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Exploring Ways to Improve DTAG Deployment Success Rates With the ARTS Pneumatic Launcher

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LONG-TERM GOALS

The DTAG was originally developed to record an animal's responses to acoustic stimuli, such as naval sonar signals, and the traditional method for deploying these non invasive (suction cup) tags on large and mid-sized cetaceans has been to use long carbon fiber poles (Moore *et al.* 2001, Johnson and Tyack 2003). This technique works well with some of the large whales, but some mid-sized cetaceans (e.g., beaked whales, minke whales) tend to be quicker, more maneuverable, and elusive, making pole tagging rather inefficient (Johnson and Tyack 2003). The goal of this project was to develop a system that launches the DTAG through the air using a pneumatic launcher (Aerial Rocket Tag System, or ARTS), in order to extend the tagging range and thus increase tag deployment rate. A preliminary version of the ARTS-DTAG system has already proven to have potential in improving tagging efficiency, particularly with "difficult" whale species (Kvadsheim *et al.* 2009). However, this system needed improvement in several areas to become operational. This project included redesign of the ARTS-DTAG system compared to the 2009 version and an extensive test program, including ballistic testing in the lab, at sea testing on a floating dummy whale and a field trial with tag deployments on minke and pilot whales.

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Figure 1: The new ARTS and a dummy DTAG (left); shooting platform on the tag boat, and the ARTS with a new sight (right)

APPROACH

To optimize performance of the ARTS-DTAG system, we have modified certain details and components; the DTAG fairings have been strengthened, three different shock absorbing robot configurations have been tested (one central spring, four springs, no spring), and a different shock absorber system has been developed, (the giraffe leg technique or GL, Figure 2), which has the shock absorbing component in front of the tag. The ARTS carrier was made lighter and various weight balancing options have been tested to assure better aerodynamics and reliable flight stability. The GL shock absorber is made of three soft rubber studs which improve the damping capability of the ARTS carrier and reduce the sliding and rebounding of the tag upon impact with the tagged animal. The floating material was changed from divinycell H80 to the lighter ethaphom 220. A new sight arrangement was constructed, and this has made the targeting more precise and robust (Figure 1). The planned construction of a quick release pressure valve to adjust the ARTS launch pressure on sudden close up approaches was not feasible with the low pressures being used (<12 bar). We added a water-surfing rim to the ARTS carrier, integrated in the flotation of the carrier system, to test the possibility of attaining tag attachments when a launching resulted in a hit just before the waterline of the animal.

Our GL system consists of three studs made of flexible material mounted on the robot arm and placed around the DTAG housing where the DTAG electronics are located. Major effort went into finding and testing the right material, as well as the right length and angle of the studs. The final version of the GL is made of polyurethane (shore-70A) and the three studs are 20mm in diameter and 60-80mm long. Half of the surface at the end of the stud is angled 135 degrees compared to the orientation of the suction cups, and all three studs are angled 120 degrees compared to the DTAG. With this configuration, once the tag is launched the studs will open up on the target and flex, and then absorb a major part of the impact energy. The distance from the stud end to the bottom of the suction cups is 25 mm when using 80 mm studs (Figure 2).

Figure 2: the new 1- and 4-spring shock absorbing robot (left) and the GL (giraffe leg technique) with 3 studs (right)

WORK COMPLETED

During the testing period various dummy whale targets were constructed for both the laboratory and field tests. The final laboratory version was a hard packed plastic structure of 50x70 cm wrapped in a 12 mm rubber coat, with a target area of 0.35 m^2, while the field test floating dummy whale was constructed with a 0.9 mm curved steel plate of 100x240 cm and coated with the same rubber layer. Both target designs provided the capability of adjusting the angle at which the tag struck the target. Three different ARTS carrier-DTAG robots were designed, fabricated and tested: 1) the old version (rigid robot), 2) a new one with a central spring, and 3) a new one with four springs. The central spring robot did not work well due to instability during launching, so we tested extensively the new robot with four springs with or without a water-surfing platform to compare with the results of the 3S-2009 cruise (rigid robot).

Extensive testing of the ARTS carriers were performed during the winter of 2009/2010, including a total of 308 launching tests on a dummy whale in the test laboratory, and a total of 47 tests on a dummy whale at sea. The initial tests in the laboratory were performed at a distance from the target of 10 m, and used different pressure ratings for the launcher (8, 10, 12 bar). We began our project by testing the original robot used in 2009 with the addition of one rubber stud and then of three rubber studs (GL system). In order to help our analysis of the tag trajectory and impact we videotaped all of the launchings. The three-stud configuration combined with the new four spring robot proved immediately to be very effective in shock absorbing and sliding reduction.

The dummy whale was always kept wet and initially angled at 90 degrees to the tagger. The new sight system and increased pressure resulted in significantly improved accuracy of the system during lab-testing, with close to a 100% hit rate within the target surface. Testing with chamber pressure on the ARTS from 8 to 12 bars gave us a variable curved trajectory, but with sight practice we obtained acceptable hits within this pressure range. As the main focus of the project was to increase the precision of the ARTS-DTAG system, while at the same time limiting the damaging impact forces on the DTAG electronics and preventing sliding and rebounding of the tag on the animal, we restricted the launching pressure to 10 bar for a 10 m target distance, and started to test the impact forces and their absorption during the hit. During the ARTS-DTAG stress-sensor test in Horten on 10 March 2010, the above illustrated setup was tested (Figure 2).

The next step was to change the angle of the target to create a more realistic scenario, closer to a field operation. The dummy whale was angled to 40-60 degrees, and the launching values and

distance were kept at the same levels of 10 bar and 10 meters. With this configuration the ARTS-DTAG system was still robust, and although we experienced some rebounds, more often the DTAG slid a little on the dummy whale and stuck. However, this often happens during pole tagging as well.

Finally, we tested the ARTS-DTAG setup using a floating dummy whale at sea, and completed a series of launchings on this target using 10-11 bars at a distance of 10-11 meters (Figure 3). We used the final version of the carrier (called ARTS10) with 80mm studs from the test setup, adding the forward foam unit, which acts as a “water jumper” when the carrier hits the water just before touching the animal.

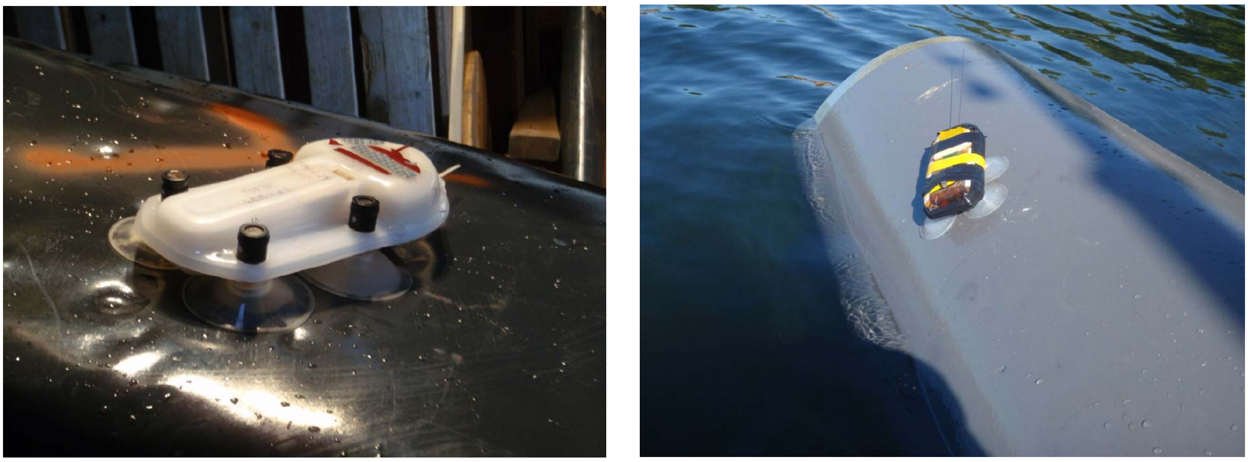

Figure 3: testing a DTAG on a lab dummy whale (left); testing a DTAG on a floating dummy whale (right)

Field Testing on Whales During 3S-10
The following priority list was compiled in preparation for the sea trial:

1. Tagging with the ARTS10 with forward foam (water jumper) unit, using 10 bar from distances of 8-12 meters
2. Tagging with the ARTS10 without foam unit, using 10 bar from distances of 8-12 meters
3. Tagging with the ARTS 09 using 10 bar from distances of 8-12 meters, to compare with the ARTS10
4. Tagging from a platform on a small tag boat
5. Tagging from a larger vessel
6. Tagging with GL with variable lengths (from 60 to 85mm)
7. Tagging with variable GL angles and variable GL foots
8. Experimental tagging on animals from variable angles - a key issue in tagging operations
9. Experimental tagging over longer ranges
10. Experimental tagging with a dummy of the new DTAG3 (DTAG3), with a VHF radio unit.
11. Experimental tagging with a FFI rescue tag holding a VHF radio unit only (this is a tag placed on a group member when a DTAG stops transmitting, in order to keep track of the tag).

The Bolga, a 52 feet vessel, was chartered for this trial in Vestfjorden, Norway, in the period from May 19 to June 9 2010, and we used the work boat MOBHUS of the research vessel Sverdrup as a tagging and tracker boat (Figure 4).

Figure 4: the tagging and tracker boat MOBHUS (left); the Bolga during tracking of a minke whale (right)

During our field period the tagging opportunities were limited to four encounters of pilot whales and two encounters of minke whales, resulting in a total of 16 launchings of the DTAG and dummy DTAG on pilot whales and four launchings on minke whales. No encounters of killer whales were made during this trial, despite the considerable effort that was invested in searching for this species. Several days were also lost to bad weather.

RESULTS

Several modifications were introduced to the ARTS system in order to make it a reliable delivery system for digital recording tags (DTAGs). We have increased the ARTS launch pressure and the precision of the system has thereby improved. We have also designed and tested a new shock absorbing ARTS carrier-robot-system, which reduces tag sliding and rebounding upon impact, and which resulted in a tag attachment upon every clean hit of the whale without damage to the DTAG or strong reaction by the tagged animal. A total of eight pilot whales and one minke whale were tagged with the ARTS-DTAG system during our field trial in May-June 2010. However, the ARTS-DTAG system still needs some modifications and adaptations to the new generation DTAG (DTAG3) to improve its performance.

In Table 1 the details of every ARTS-DTAG launching are described. The ratio of hits and misses was roughly 50/50, while the ratio of hits with long and short tag durations was 40/60%. Thanks to good photo and video documentation we were able to analyze each tagging event and understand the details of the tag launch and attachment (Figure 5). A total of eight pilot whales were tagged with the ARTS-DTAG system, five with a dummy DTAG with a VHF radio unit and a TDR (WC-Mk9), one with a rescue tag holding only a VHF radio unit, and finally two with real DTAGs. One minke whale was tagged with a dummy DTAG. The release system for the dummy DTAG was set at 2-4 hours, 6-8 hours, or without a release system (the natural leakage of the suction cups will release the tag in about 72 hours or less). The tag duration was variable, and tags came off ahead of the release time five times. The longest tag attachment was 42 hours to a pilot whale using a dummy DTAG with VHF and no release set.

A dummy DTAG with a four hour release attached to a pilot whale was tracked from both the small boat (MOBHUS) and the mother vessel (Bolga), and the tag attachment was well photo-documented during the tracking period. After five hours two of the suction cups were loose, but we then suddenly lost all signals from the tag. We thoroughly searched the area without results. The tag was probably damaged and or destroyed by the group of juvenile pilot whales (this has happened before with pilot whales).

The dummy DTAG deployed on a minke whale had a release set time of 2-4 hours, and after two hours and 40 minutes the tag released and was picked up. During the tracking of the minke whale we used a new radio direction finder produced in Norway in 2010, the Horten Direction Finder (HDF), while the tracking of the animal was logged into an event-logger from IMR, Bergen (Norway).

Figure 5: Pilot whale (left); minke whale (center); pilot whale (right)

All tagging approaches were documented as well as possible by photo and/or video, resulting in an in–field option to modify details of the tagging equipment. This work was important throughout the field work. The limited number of whale encounters resulted in a reduction of the number of variables initially intended to be tested. However, the pilot whale is a suitable target species for testing different tagging scenarios, and therefore during the four days of encounters with this species, we managed to cover many of the field issues to be tested. The only problem with pilot whales is that groups of juveniles tend to be extremely playful and rough, resulting in shorter deployments, and sometimes the tags are damaged. Except for test points 6 to 9 most of the issues were tried, although some of them just briefly (see Table1). The hit and miss ratio of 50/50 during field testing vs. close to 100% hits during lab testing indicate that the ARTS-DTAG system still needs improvement to increase resiliency. We think the main problem when working at sea with moving targets is the shooter’s ability to make quick decisions about range to target and thereby choose the appropriate launching pressure. It is a difficult issue in the field to know if a whale is surfacing at 8, 10 or 12 meters (just for a few seconds!). One option is to lighten the ARTS carrier even more to achieve a straighter flight from launcher to target. However, the ARTS carrier with shock absorbing robot system (four springs plus GL) developed during this project proved very effective. Upon each clean hit the DTAG attached to the whale, without rebounding or sliding too much, and no DTAG was damaged by excessive launch force.

The reason for some of short tag durations are photo documented, showing that suction cups are at the side of the dorsal fin or the keel of the animal, while for some other deployments there are no obvious reasons other than animal behavior. This year we experienced a number of good tag attachments that came off too soon, although this is a known difficulty when working with pilot whales. Unfortunately, we were not able to test different tagging angles; however, this is an important issue to be tested in future tagging projects. If we could use a system that allowed us to

attach tags at angles of up to 40-50 degrees, the tagging options would be much greater than with the current approach, with tagging angles of 80-90 degrees.

The new direction finder built by FFI, HDF, gave us good control with the tagged animal up to 2 nautical miles during the tracking from the tag boat, and this unit will be a new tool for tracking projects using radio tags and DTAGs. The event logger functioned fairly well in the small tagboat setup. We had some power issues, and for future field work from a small boat the current IMR system (big box holding a PC) should be replaced with a smaller system like a PDA-GPS unit with a vocal input. A marine mammal observer unit like this would be useful in describing field events from various platforms.

Figure 6: DTAG on a pilot whale (left); dummy DTAG on a minke whale (center); dummy DTAG on a pilot whale (right)

Table 1: Sea Trial Summary

Date	Species	Bar	m.	Ang.	Hit	Time on	Doc.	Tag	Carrier	Platform	Comments
24-May	Pilot whale	10	10	70	BD	null	photo	dDTAG	ARTSC&WJ	Mobhus	Rebounding on floater
24-May	Pilot whale	9	10	85	LD	16min	photo	dDTAG	ARTSC&WJ	Mobhus	Water touch ahead of hit
24-May	Pilot whale	10	12	80	miss	null	photo	dDTAG	ARTSC&WJ	Mobhus	Late timing
24-May	Pilot whale	9	11	90	miss	null	no	dDTAG	ARTSC&WJ	Mobhus	Water in front
24-May	Pilot whale	9	10	90	DFF	56min	photo	dDTAG	ARTSC&WJ	Mobhus	Ridge front DF, data on loost tag
24-May	Pilot whale	9	10	70	miss	null	photo	dDTAG	ARTSC&WJ	Mobhus	Late timing
24-May	Pilot whale	9	8	80	miss	null	no	dDTAG	ARTSC&WJ	Mobhus	To high, water
24-May	Pilot whale	10	11	90	LL	42h	photo	dDTAG	ARTSC&WJ	Mobhus	Low lateral - launched Resque tag
26-May	Pilot whale	6	10	85	DFR	8h+	photo	Rtag/VHF	Rescue tag	Mobhus	Base right dorsal, pod left behind Bolga to Bodø
26-May	Pilot whale	10	10	85	FD	null	photo	dDTAG	ARTSC&WJ	Mobhus	Late timing, rebounding
26-May	Pilot whale	9	11	80	BD	30min	photo	dDTAG	ARTSC&WJ	Mobhus	Slides up to back of DF, 2 SC attachment
28-May	Minke whale	8	10	90	miss	null	photo	dDTAG	ARTSC09	Bolga	Low front, in water
28-May	Minke whale	10	9	90	miss	null	photo	dDTAG	ARTSC09	Bolga	High in water, same animal
28-May	Minke whale	9	5	85	TD	2h46m	Video	dDTAG	ARTSC09	Bolga	High impact. 4h with release
31-May	Pilot whale	9	10	70	FD	4.24h+	photo	dDTAG	ARTSC10	Bolga	Slides to ridge front dorsal, track 4.24h then silent
1-Jun	Pilot whale	9	10	80	miss	null	photo	DTAG	ARTSC10	Mobhus	Low waterline in front
1-Jun	Pilot whale	10	10	75	Flank	30min	photo	DTAG	ARTSC10	Mobhus	Waterline
1-Jun	Pilot whale	10	10	80	miss	null	photo	DTAG	ARTSC10	Mobhus	Low waterline in front
1-Jun	Pilot whale	11	11	80	DR	60min	photo	DTAG	ARTSC10	Mobhus	High impact , good attachment
6-Jun	Minke whale	10	9	45	miss	null	photo	DTAG	ARTSC10	Bolga	To high, in water
7-Jun	Pilot whale	6	10	45	miss	null	photo	DTAG3	TestC	Mobhus	Low front, in water
7-Jun	Pilot whale	6	10	90	miss	null	no	DTAG3	TestC	Mobhus	Low front, in water
7-Jun	Pilot whale	7	11	85	DL	null	no	DTAG3	TestC	Mobhus	Rebounding from dorsal fin

IMPACTS/APPLICATIONS

During this project we have managed to improve the precision of the ARTS-DTAG system due to more power as well as better sights. We have achieved this by designing a shock absorbing robot-carrier which reduces rebounding, sliding of the tag upon impact and damage to the tag. However, when moving from laboratory to field testing, the robustness of the system required further improvements. The new DTAG3, which is smaller and lighter, will hopefully improve the ballistic difficulties and allow us to improve precision and range without increasing the power of the

launcher. However, this implies transferring the current ARTS-DTAG system to DTAG3, using the knowledge obtained in the current project to build a light weight shock absorbing ARTS-DTAG3 robot arm.

REFERENCES

Moore MJ, Miller CA, Morss MS, Arthur R, Lange W, Prada KG, Marx MK, Frey EA. 2001. Ultrasonic measurement of blubber thickness in right whales. Journal of Cetacean Research and Management 2:301–309.

Johnson MP, Tyack PL. 2003. A digital acoustic recording tag for measuring response of wild marine mammals to sound. IEEE Journal of Ocean Engineering. 28:3-12.

Kvadsheim P., Lam F-P., Miller P., Alves A. C., Antunes R., Bocconcelli A., Van Ijsselmunde S., Kleivane L., Olivierse M. and Visseur F. 2009. Cetaceans and Naval Sonar – the 3S-2009 Cruise Report, FFI – report 2009/01140.